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The audit od complex systems using an exploratory approach
(Discussion paper no. 4)

Office of the Auditor General of Canada

Bureau du vérificateur général du Canada

DISCUSSION PAPER No. 4

THE AUDIT OF COMPLEX SYSTEMS USING AN EXPLORATORY APPROACH

BY
J.R. Rutherford, P.M. Willey, M.I. Zelman

MAY 1982

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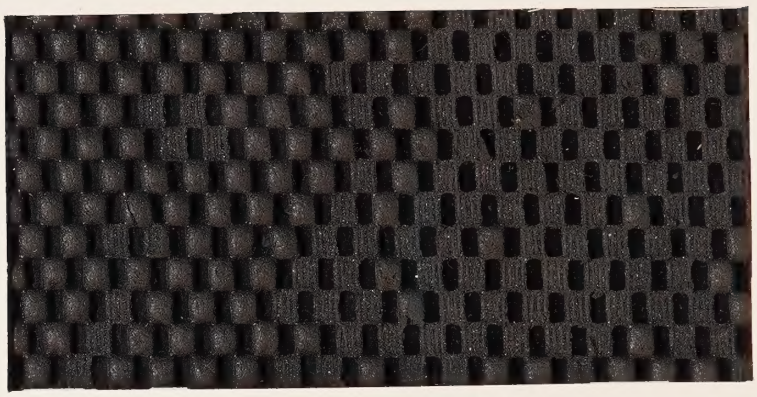

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Introduction and Synopsis

This paper describes an approach for solving the familiar dilemma of balancing audit needs with limited audit resources. It allows the auditor to look at the organization being audited in a way that quickly identifies the key systems and major control issues. The approach provides a method for a program-oriented audit of a department.

The exploratory approach is a staged process in which data collection alternates with its analysis and evaluation. The initial data collection leads to the development of a first theoretical model of the organization. This model shows how the auditor first believes the program might logically be organized to do what it is supposed to do; it is called a system logic model. This first model is then analysed to identify what are thought to be key functions of the organization being audited. Further information is collected, with particular emphasis on these identified functions. Analysis and collection are alternated, and conclusions are displayed in more refined versions of the system logic model. This refined model can be used to explain to management of the organization being audited the auditor's perception of the organization. It helps to validate the auditor's understanding of the organization.

Because comparable logic models are built up by the various specialists on the audit team, their models can be compared to give a balanced overview of the organization. Logic models can also be used in selecting the issues for detailed audit. Since the models visually display the relationships between various systems and processes, this facilitates the comparison of the need for detailed audit information being obtained on the various systems and sub-systems.

Example

The general purpose accommodation program of the Department of Public Works is used here as an example. It was selected for several reasons, including the convenient dimensions of this particular program-oriented audit and the fact that the audit team had to apply the full analytical process of the exploratory approach. Some background on the dimensions and characteristics of the Department and program are given.

The Department of Public Works is the federal government's major realty organization. Its primary role is to provide government departments and agencies with accommodation economically and efficiently; it does this by acquiring, operating and maintaining buildings and by maintaining the government's central real property inventory. In 1977-78, the accommodation program expenditure was approximately 80 per cent of the Department's $830 million total program expenditure. Approximately 6,000 employees work in the accommodation program; most of the 1,336 employees in the professional and technical services

program do work directly or closely related to the accommodation program. The general purpose accommodation activity accounts for about two-thirds ($442 million) of the accommodation program's resources.

The Theoretical Model of Accommodation Services

As a first step in this approach, the auditor develops a system logic model of the general purpose accommodation program (Figure 1) based on reading and analysing program forecasts, the Estimates, annual reports and publications on private sector or real estate management. This model then shows how the auditor at first believes the accommodation program might logically be organized to do what it is supposed to do.

An accommodation program would begin with a demand forecast for its services and a comparison of this demand forecast with a list of available inventory, thus establishing a net shortfall or surplus. From this comparison, the program can define its options, analyse them and make recommendations to meet the demand. The decisions would be made and the accommodation acquired, operated and maintained for the duration of the demand. Finally, the accommodation would be disposed of. This logic is displayed in Figure 1.

Developing a Balanced Perspective

A theoretical model such as Figure 1 is the basis for parallel audit activities by different specialists. One problem associated with conducting

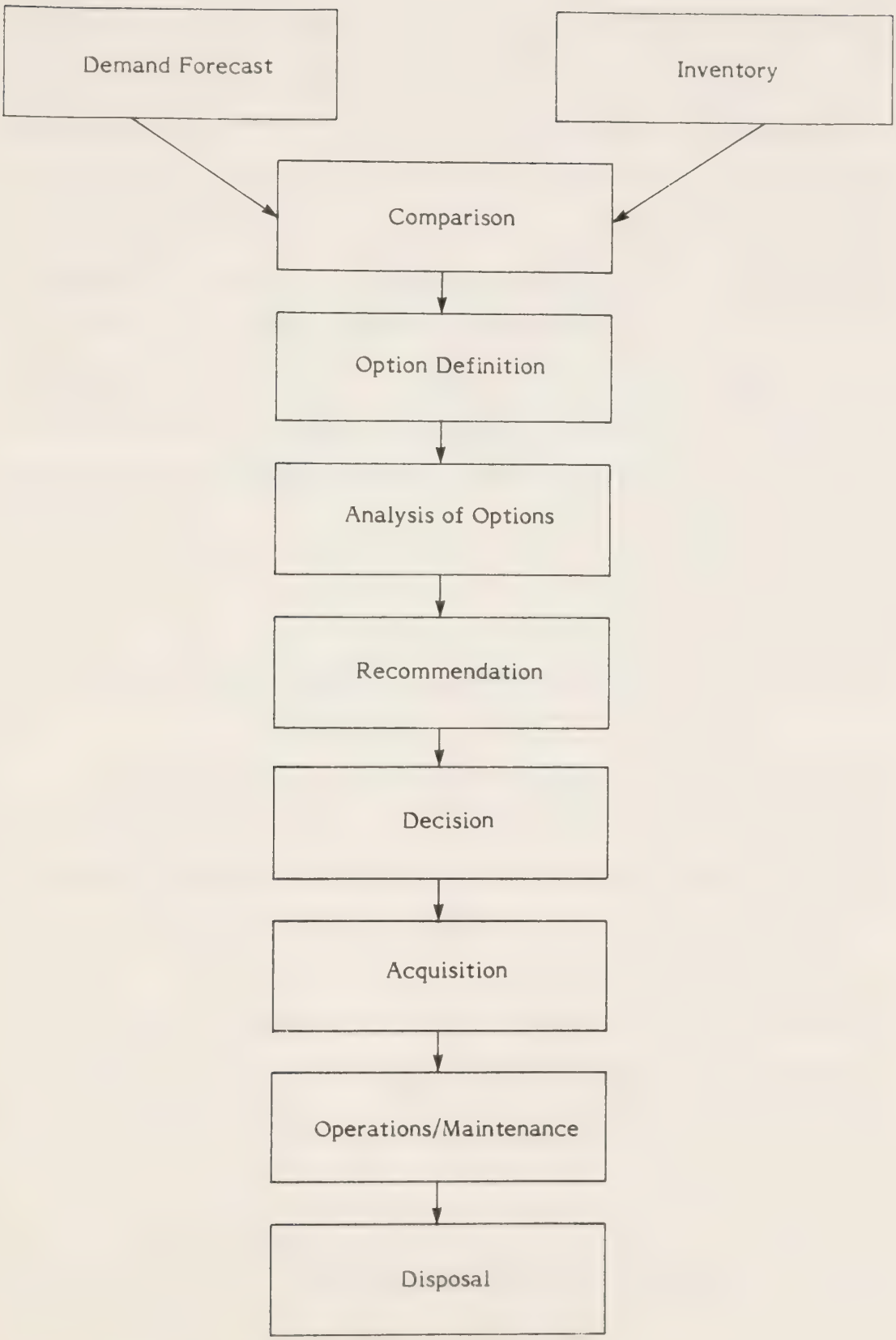

Figure 1: The first theoretical model of the way an accommodation provision business might logically be expected to operate.

comprehensive audits of complex systems is that of developing a balanced perspective of the program being audited while using the required specialists as auditors. Specialists in different areas will usually perceive an organization in different ways. To overcome this difficulty the method described provides a basis for developing the needed common perspective, by displaying clearly where specialist perspectives differ. In the example, we describe first the development of a logic model for the program-oriented management perspective of the accommodation program. This is followed by a description of how models would be made for the financial management perspective, the EDP perspective and, by implication, any other perspective. We then discuss how the common perspective will be developed.

The Program-oriented Management Perspective Logic Model

The auditor transforms the first theoretical model through a series of interim system logic models into a final logic model. Interviews will have validated the auditor's understanding of the accommodation program; advice will have clarified that understanding within the audit context.

Figure 1 acts as the base on which successive "layers" of information can be added, piece by piece. The logic model will be subject to modification and addition throughout the whole of the audit, not just during the preliminary survey.

A simplification of a typical final logic model is shown in Figure 2. The final logic model is to reflect the auditor's developed state of knowledge; help

identify the key activities, systems and controls; highlight the needs for specification of criteria; and provide a basis of comparison, allowing proper selection of issues for detailed audit.

Exploring the Program Being Audited

The auditor uses the first theoretical logic model of Figure 1 to make a tentative identification of the key systems. This identification directs attention toward what are initially perceived as probably important matters. At this early point, the key systems are identified, using Figure 1:

- demand forecast;
- option analysis; and
- acquisition.

It may be found later in the survey that this first identification is faulty, but, even so, the model guides the auditor's exploration of the program being audited and increases understanding.

Using the general approach, more data is collected with emphasis on the identified systems. Subsequently, there is a review of all the information and a reassessment of what appears to be important. Collection and assessment alternate as the logic model is elaborated until the audit team is confident that it properly understands the program being audited.

As an example of the build-up of understanding, the auditor learns that demand forecasting, although key to the general purpose accommodation function, is not a feasible expectation in the Department of Public Works. Demand for accommodation is determined by government policies and by creation of departments, their relocation and degree of decentralization. The Department of Public Works is often the last to know. Hence, with demand in the hands of Government, good forecasting is not within the control of the Department. Therefore, the resolution of this issue is outside the scope of our audit. The important issue of economy in government remains, however, and this could be the subject of a government-wide study.

The auditor learns that options analysis is, in fact, a critical function. Here, the first analysis has proved correct. As for what the options analysis process should do, criteria for this exist and were reported in our 1978 annual Report. Further, the auditor learns that the acquisition process, which is project management, is not costly even though it is important. Capital costs represent about one-quarter of the total accommodation costs, and the actual acquisition process represents about one-tenth of that quarter. The auditor discovers that reliable feedback loops for operations/maintenance costs to building design and options analysis are essential to cost control. Such elements of cost are, in turn, essential in estimating life cycle costs -- one of the criteria in options analysis. One learns that control of operating costs is feasible largely only at the building design stage and that maintenance costs are controllable at the building design stage and throughout the occupation of the building.

This example demonstrates that increasing knowledge allows continuous modification of the theoretical model eventually to provide the final logic model with its functions and feedback control loops.

The actual final logic model for the accommodation program was immensely complicated. It displayed dozens of interconnections among many management systems and sub-systems. For simplicity in this example, Figure 2 is represented as being the final logic model of the general management function of the accommodation program. The "completed" Figure 2 shows the auditor's understanding of how an accommodation program would logically be expected to operate. Each box represents an identified key system that is a candidate for further audit examination. The visual display of the relationships between and among the key systems makes it possible for the audit team to make an informed, although qualitative, assessment of the relative importance of each key system. The most important are agreed upon, and these are selected for further more detailed examination.

In continuing our example, we examine only three systems:

- options definition and analysis;

- feedback of life-cycle operations/maintenance to options analysis; and

- operations/maintenance.

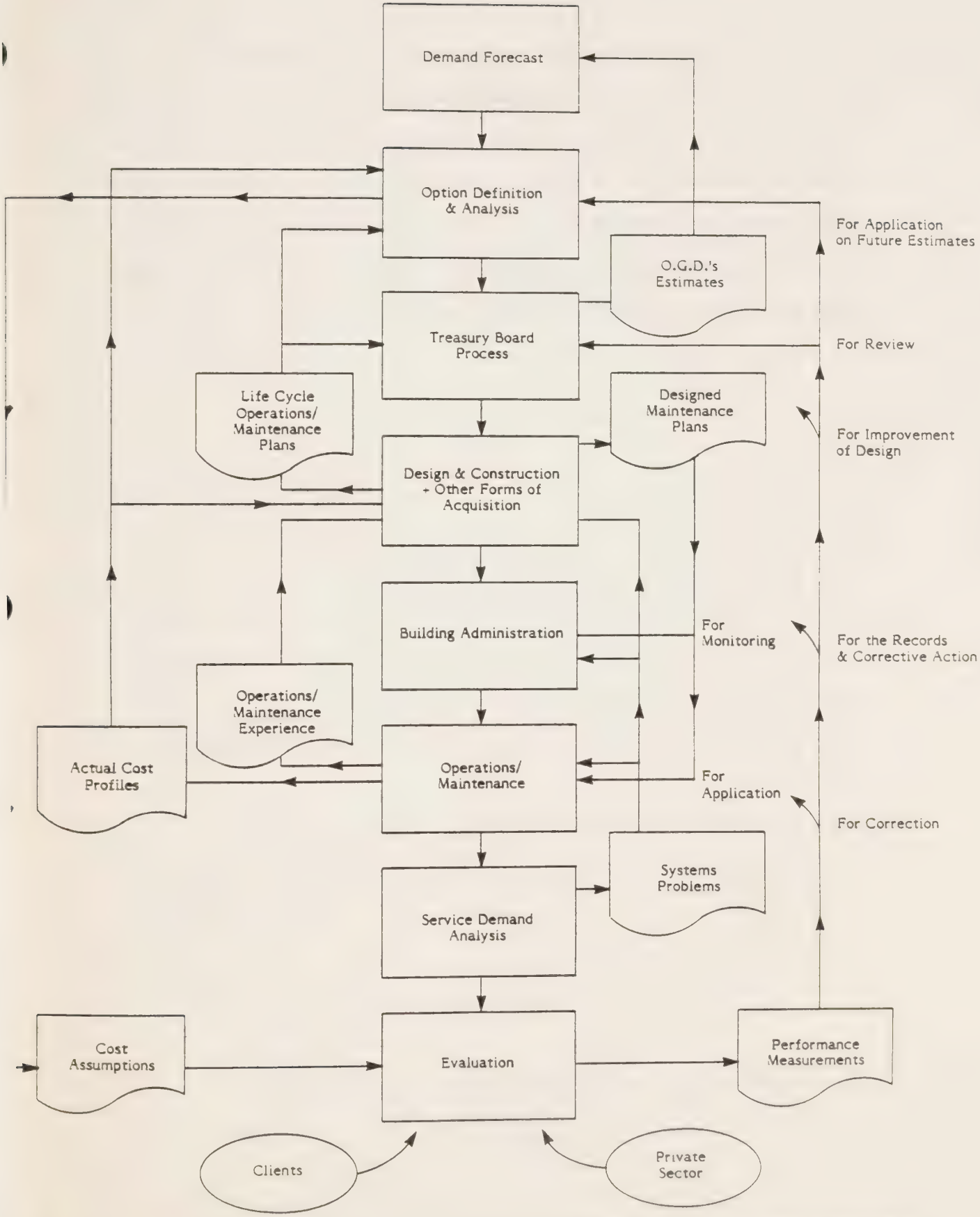

Figure 2: A representation of the final logic model for the management perspective of the General Purpose Accommodation function.

Two further uses of the logic model should be noted. The first is that the boxes on the logic model represent logical ways to group the audit criteria. This is particularly important where a number of auditors are working simultaneously on similar entities. By having a basic logic model with similar criteria, it is possible to get inter-team uniformity. A second use of the logic model is as a basis for the working paper file system. In one example, three new and informative files could be created with the titles: Options Definition, Feedback of Costs, and Operations/Maintenance.

Option Definition and Analysis

The auditor specified and validated criteria for options analysis with management of the program being audited. Of these criteria, the most important was that requests for funds should be supported by accurate and complete documentation. This criterion implied a need for life-cycle costing and accurate estimates of comparable market rents and rental potential.

The options analysis function was reviewed by examining some recent cases. A cursory review at this stage of the audit showed three potentially damaging weaknesses:

- life-cycle costing was omitted;

- calculation of financing costs was inaccurate in one case; and

- revenue estimates were imprecise.

At this point, the auditor can foresee that such weaknesses would have significant adverse effects on any building program and plans a detailed examination of the options analysis function to ascertain whether these suspicions of weakness can be supported. At the same time, the auditor considers planning an audit of a recent acquisition to see if these suspected weaknesses had adverse effects in that case. This has to be done to show that weakness suspected in the general management process actually would lead to adverse effects. It is equally necessary to demonstrate the absence of compensating controls. In this latter case, the auditor must be satisfied that remedying the weakness in the general management is necessary to correct the problem.

It was decided to audit a recent acquisition project. The primary objective of this examination was to identify and report on the consequences of all suspected weaknesses in the general management process of the accommodation program. The suspected weaknesses in the options definition and analysis function would probably have effects such as poorly estimated costs, inaccurate revenue forecasts, and user needs not met. If such deficiencies were to be found in the audit of the recently completed project, a second level of detailed examination would quantify the impact on cost of such deficiencies.* Further detailed examination would be necessary to determine whether such deficiencies in the project

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* A secondary objective of such an audit would be to evaluate the management controls particular to the project.

were, in fact, caused by the weaknesses in the options definition function of the general management process. If it were to be subsequently proved that the weaknesses in the options definition and analysis function caused or permitted such deficiencies, then a recommendation to strengthen and improve the analysis function would be made. This rigorous proving must be done to demonstrate that the correction of the weaknesses in the general management system is likely to prevent recurrence of similar deficiencies in other building projects. This level of intense analytical effort is required if eventual recommendations are to be effective when accepted and implemented.

Conversely, suppose that the preliminary evaluation of the options analysis function revealed no potentially damaging weaknesses. The importance of the options analysis function would, however, require that substantive proof of its effectiveness be obtained for inclusion in the overall evaluation of the management processes. Consequently, an audit plan to verify the suspected strength of this important control would be developed. Such a plan might require that the planning stages of a number of major buildings projects be reviewed in detail to verify that the options analysis function had produced the desired results.

Feedback of Operations/Maintenance Costs

Assume that preliminary evaluation indicates to the auditor that operations/maintenance costs are not fed back to either design or options analysis. The auditor would then develop a plan to verify this observation during the execution phase of the audit. In the detailed audit, documentation would be reviewed,

operating personnel would be interviewed, and procedures would be analysed for completeness and compliance. Finally, structured interviews with key managers in the organization being audited would include questions such as:

- Is this control link a logical part of the process?

- Is such a control link present?

- Is such a control link practically and economically feasible?

This approach ensures that management will not be surprised by the audit observations, an important step toward eventual action on the recommendations.

Were weakness of general management function to be proved, predictable adverse effects would become evident during the audit of the recent acquisition. That is, the auditor could expect to find higher operations/maintenance costs designed into the building. To examine this issue, the auditor would determine acceptable standard cost levels from private industry experience. If higher costs were found at the new building, the auditor would have to verify that these could be reasonably attributed to design and feedback issues. The auditor confirms the absence of compensating controls and again must be satisfied that a recommendation to provide for feedback of these costs to design would prevent a recurrence.

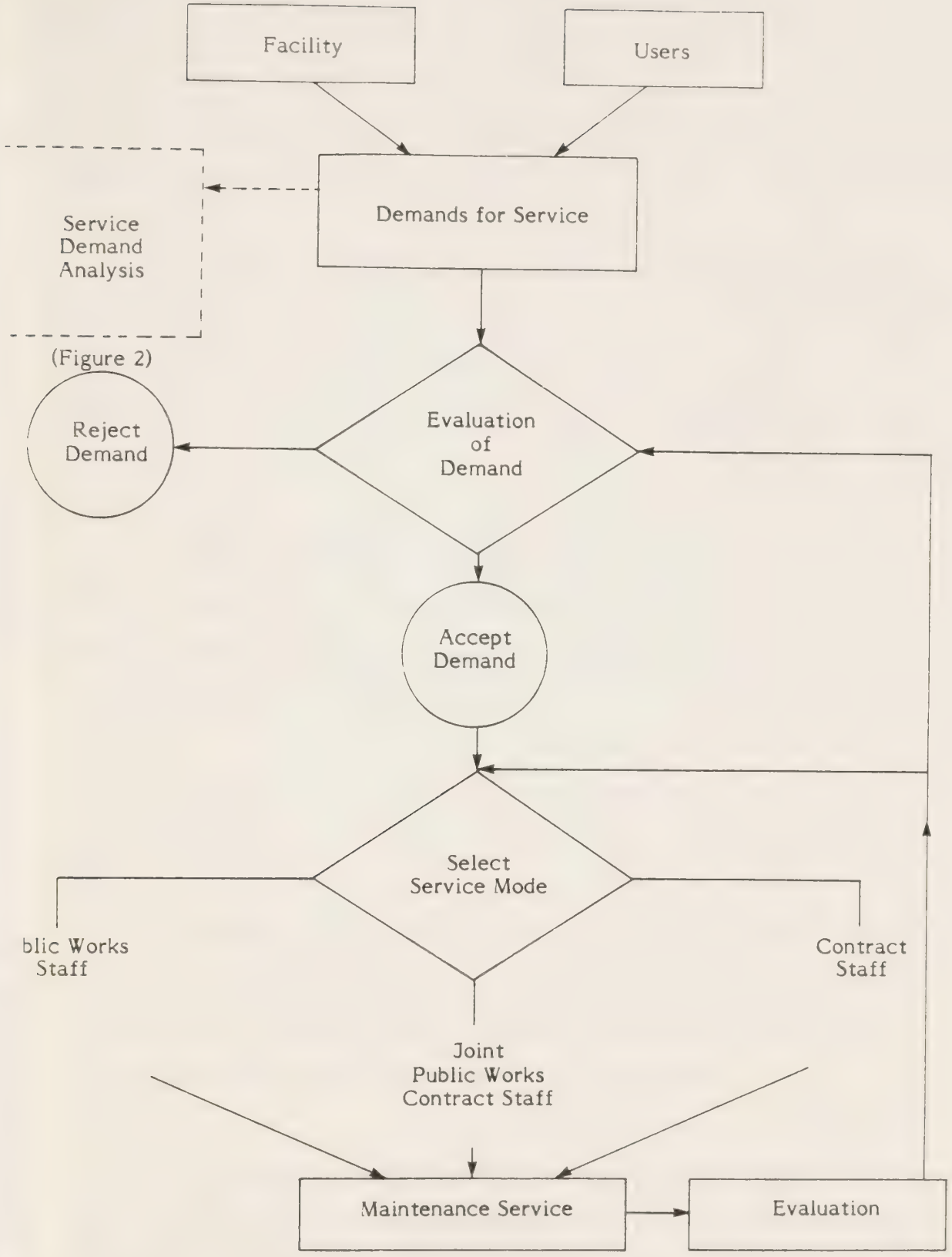
Operations/Maintenance Costs

While developing Figures 1 and 2, the auditor learns that operations/maintenance costs are controllable to some extent (but not to an equal extent) in the building design stage.

We leave to the reader the problem of drawing a theoretical model for co-ordinating building design and options definition and analysis. Such a model, an analogue of Figure 1, might represent how this co-ordination would logically be effected. This model would guide the exploratory interviews so that a final logic model for the design-options co-ordination function could be developed.

Alternatively, building maintenance costs are more determinable and more economically controllable during building occupation than at the design stage, although design intended to minimize cost is important.

Figure 3 is the theoretical model developed by the auditor to represent how the maintenance function would logically be organized. From users come demands for maintenance service that require evaluation and decisions about the acceptance or rejection of them. If the demand is accepted, choice of service mode becomes a further necessary decision. There are three possible service modes: Public Works staff, contract staff, and joint Public Works and contract staff. The chosen mode provides the required maintenance service. After provision of such service, evaluation of service is fed back into the evaluation of demands and into future decisions on the selection of service mode.



3: Theoretical model for provision of maintenance services. Note the link with Figure 2 where the demands for service are recorded for use in the box "Service Demand Analysis".

From this theoretical model, four key control points and relevant criteria are immediately obvious to the auditor.

Evaluation of demand for service. Maintenance managers should have standards for facilities maintenance so that they can evaluate demands for service. For the detailed audit, the auditor would plan to establish the existence and reasonableness of these standards. In default of either or both desired states, what is the result?

Selection of service mode. Maintenance managers should have a decision procedure that selects the most economical mode. In the detailed audit, the auditor would plan to examine this decision procedure. If inadequate, do identifiable deficiencies result?

Evaluation. This should be a routine function used by all levels of management for various purposes.

Provision of maintenance services. Of the four key control points, this is the most probable location of an efficiency issue. If, for example, contract is the selected service mode, the auditor will plan to examine adequacy of procedures used to ensure cost effective use of contract personnel.

To continue this example, let us assume that the DPW staff service mode is the dominant mode of the Department. The briefest consideration of this service mode shows the provision of service as a highly probable candidate for eventual efficiency issue analysis. Again, an audit management decision must be

made. Should these lower level systems and their outputs be examined? The answer is yes only if the information is needed to support the overall opinion which is being developed.

Suppose the decision was made to audit the Department of Public Works service mode. The auditor will develop a theoretical system logic model of the management function during the preliminary survey. This model is used to guide interviews, identify key sub-systems controls, and, when the model is complete, plan the detailed audit. Figure 4 is such a theoretical model of the management of Public Works staff providing maintenance services. Demands enter the system and must be balanced against the inventory of maintenance resources. Demand and inventory are presented to the work control system which provides input to first level supervision that will be responsible for carrying out maintenance tasks. Later, there will be a feedback of performance evaluation.

There are evident links between this latest system logic model and other models. The demands for service should be analysed to determine the best level of inventory for maintenance resources. The service demands analysis is a function in Figure 2. There must also be a link with the cost accounting system displayed in Figure 5, the logic model for the financial perspective of the accommodation program.

From Figure 4 the auditor sees that four key controls merit attention. All relate direct to an efficiency issue involving transforming of maintenance resources into maintained facilities. They are:

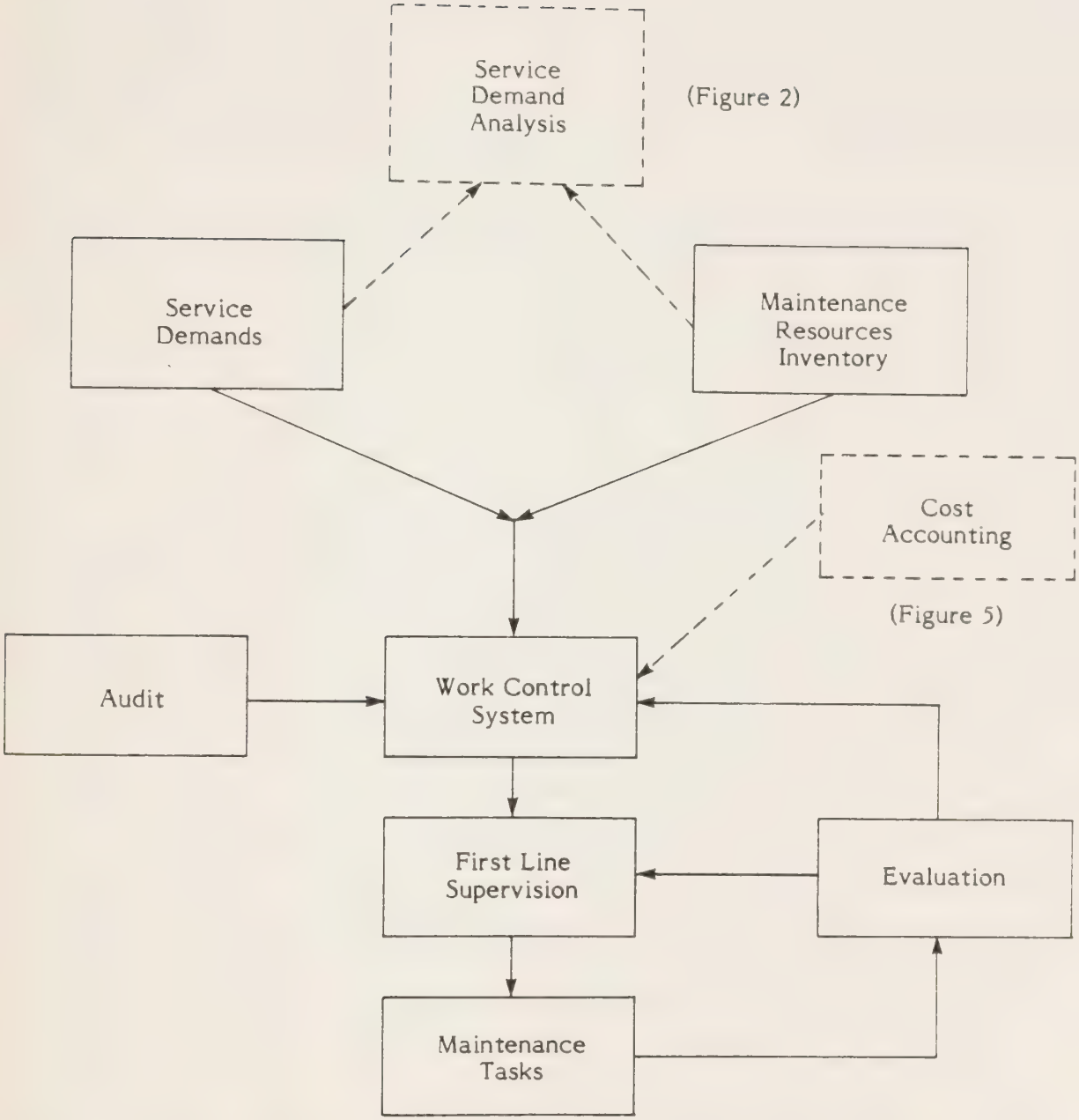


Figure 4: Theoretical logic model for management of Public Works staff providing maintenance services. The service demands link with their analysis, a function indicated in Figure 2 where the size of the maintenance resource inventory would be determined in the service demand analysis function. The work control system should be linked with the cost accounting system of Figure 5.

- work control system for estimating, scheduling and costing;

- audit of work control system;

- first-line supervision that is active, trained and well supported; and

- evaluation.

With these controls identified at this level of generality, another audit management decision must be made: Should a detailed logic model for maintenance service be developed during the preliminary survey? Or should this be deferred until the detailed audit work? The answer will be based on consideration of factors including audit resource availability, scheduling, and estimates of the probable audit effort needed. Considering only the last factor, if the audit effort is small, the detailed logic model will probably be postponed. If the efficiency issue is vital to the comprehensive opinion and the audit effort will be large, the logic model extension to Figure 4 is necessary to plan the efficiency audit. This being so, the final logic model for maintenance services will be developed at this point.

This sort of audit decision has to be made continuously during the survey stage of the program-oriented audit. Unless controlled closely, this approach to the audit of complex systems will be very costly in terms of audit resources.

Another and equally important audit management decision must be made -- how to approach this audit. Should audit of the recent acquisition project be done as a project of the accommodation audit? Should it be done separately as an audit of capital asset acquisition? In fact, the decision could well have been to audit more than one such major acquisition. Again, time, audit resource availability and scheduling must be considered. In the actual situation, separate audit was the final decision. This being so, the modelling cycle re-starts from a theoretical model of a capital asset acquisition and disposal activity. Each major auditing management decision is made from a point closer to the operating realties of the program under audit, and each decision moves the auditor still closer to a thorough understanding of the program.

The Financial Management Perspective Logic Model

In parallel with the development of the program-oriented management logic model, a financial management logic model for the general purpose accommodation program is developed. This model highlights for possible audit the financial issues in the audited organization. We present now the financial auditor's approach, seen from the exploratory point of view. We do this to clarify the relationship between the established systems approach of the financial auditor and the program-oriented approach to the comprehensive audit of complex systems. Ideally, the financial and the management aspects of the survey should be completely integrated; however, this is not always practical.

In an actual survey, the audit team would have management specialists developing Figure 1 into Figure 2. At the same time, financial management specialists develop Figure 1 into a logic model for financial management of the general purpose accommodation program. Under the survey team leader, specialists or specialist groups would co-ordinate their efforts so that a balanced perspective is developed. This modified figure is shown as Figure 5 -- a theoretical model of the financial management functions which might be identified during the preliminary survey. Many feedback loops are now shown, and some management functions have been split. The design and construction box of Figure 2 is split, as is revenue collection, an important component of building administration. All such modifications to Figure 2 are put in place to aid and establish the location and relevance of financial management functions in the accommodation program. The critical financial functions are heavily outlined in Figure 5 and will include: option definition and analysis; revenue collection; revenue forecast; project cost control; routine financial management; cost accounting; performance measurement; and management of the financial function.

Any financial management function considered important to the economic, efficient and effective management of the accommodation program will be considered for audit. A function will be audited if information on the quality of systems supporting that function will be needed to support the overall comprehensive audit opinion. Although it is unlikely that many of these functions would be audited as part of the attest of the Public Accounts of Canada, many of these would be material to the comprehensive audit opinion on the accomodation program.

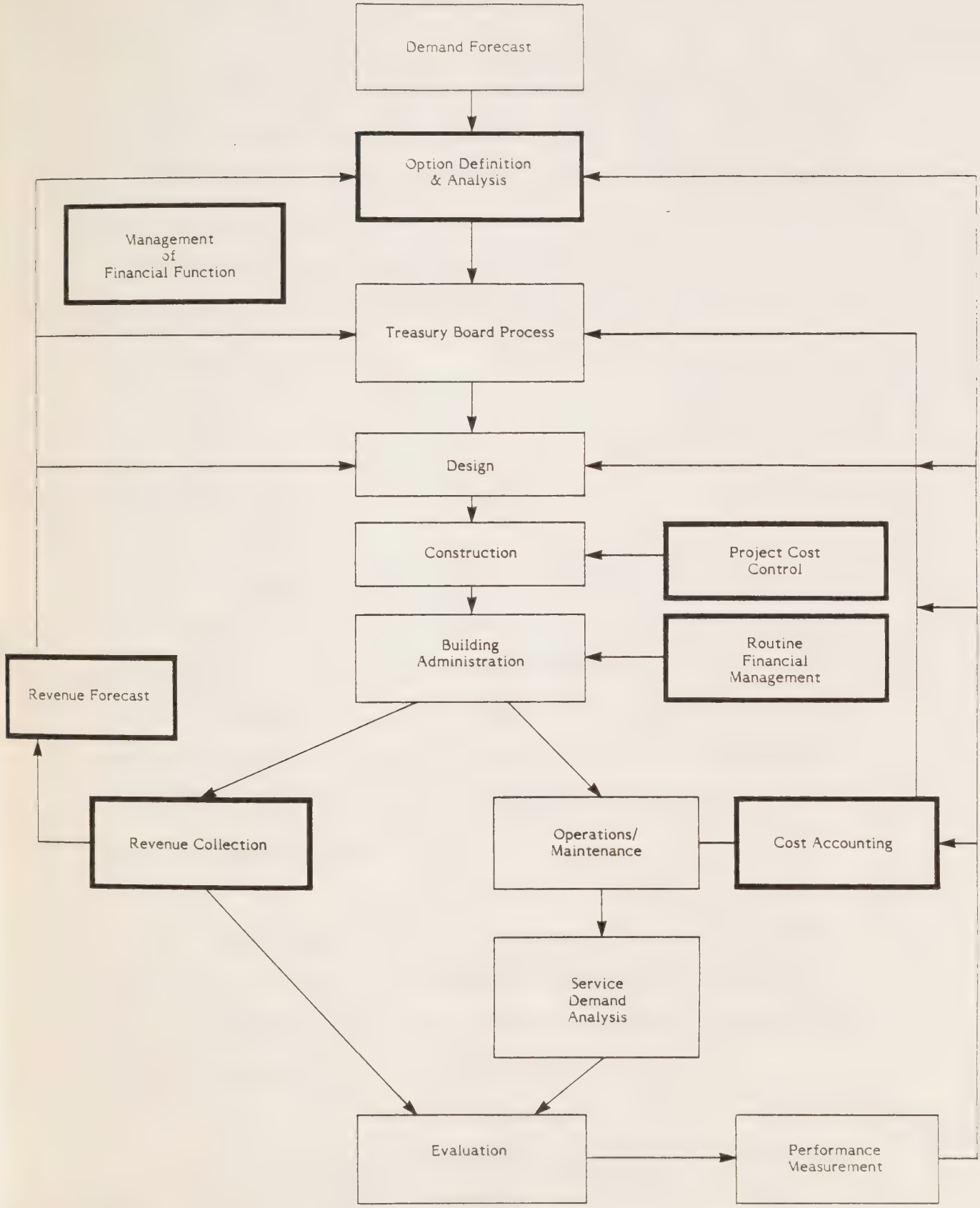


Figure 5: Theoretical logic model of the financial management functions in the General Purpose Accommodation Program. The financial functions are in the boxes with the heavy outlines.

For example, performance measurement, revenue forecasting and cost accounting each provide important inputs to the options definition and analysis function. In turn, this analysis function must perform well if value for money is to be achieved. Consequently, these three financial functions would probably be audited in detail because their individual assessment would be needed to form the overall evaluation of the quality of financial and resource management of the accommodation program.

EDP Perspective

In an audit of the EDP function associated with the general purpose accommodation program, the generic similarity of approach is maintained. To guide the audit, the location of major EDP systems will be indicated on Figure 5; this is done to produce Figure 6. This will help the auditor identify the components of the EDP system whose proper operation is necessary for effective and economic management of the accommodation program. As with Figure 5, this will be done during the survey.

A parallel audit management decision will determine if a specific EDP program should be audited. This decision, like similar decisions needed in non-EDP audit, will be affected by considerations of the expected use of the information in developing the overall comprehensive audit opinion.

Consider, for example, the computer usage at three locations in the program as shown in Figure 6:

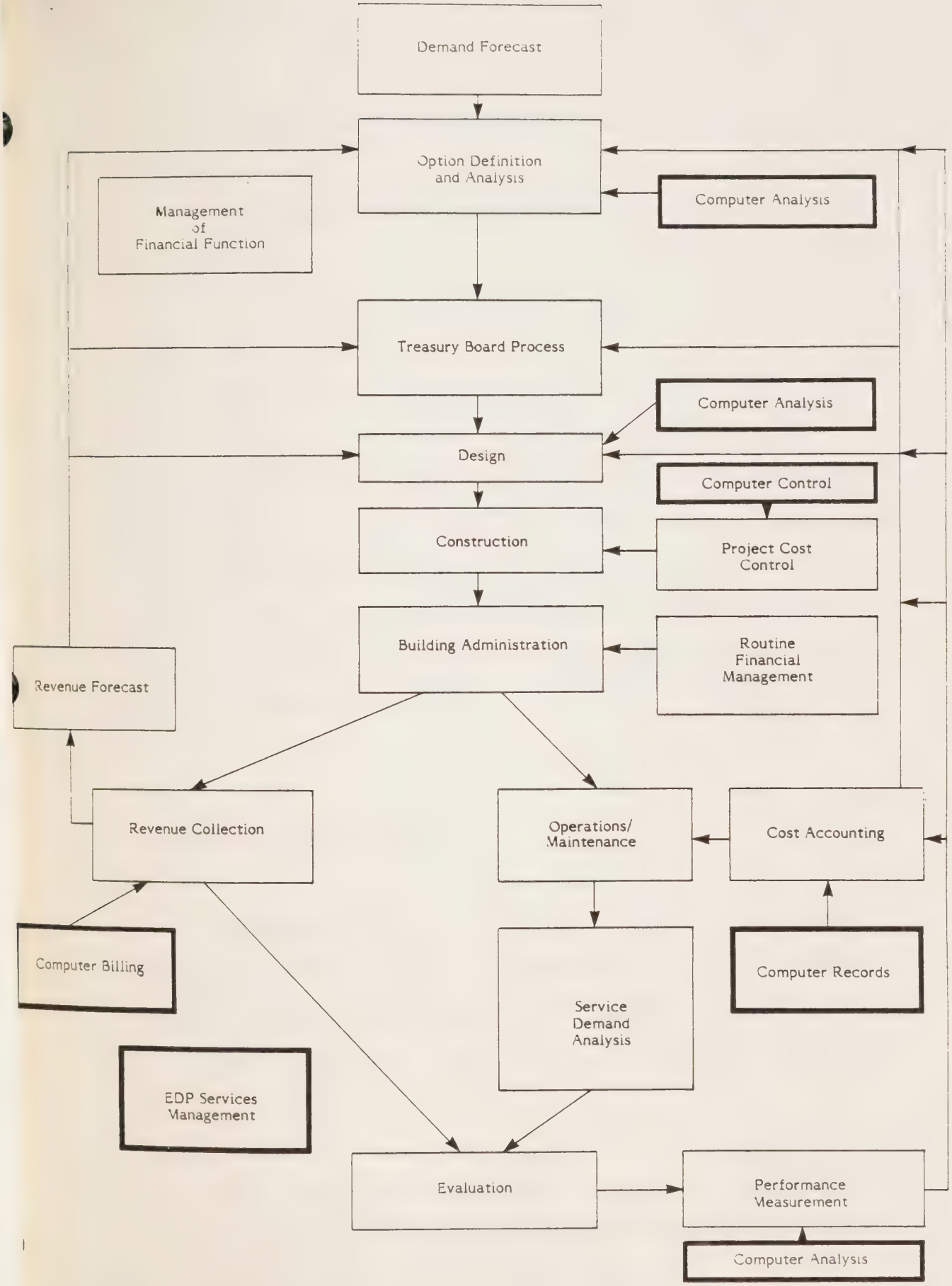


Figure 6: Theoretical logic model for the major EDP systems of the Accommodation Program. The important EDP systems are outlined heavily and connected to their respective support functions.

- at option definition and analysis function - computer analysis;

- at the building design state - computer analysis; and

- at the cost accounting function - computer records.

The first and the third are important for the overall economic acquisition and operation of major buildings. The second might be presumed to be adequate because of the wide availability of packaged computer software and hardware; it would not be audited further. In the EDP detailed audit, the first and third would be reviewed only to ensure that they did effectively what they were supposed to do. They would probably not be reviewed to determine whether they were themselves economic and efficient. This is because their costs are relatively insignificant in comparison with those of the accommodation program itself.

Developing a Balanced Perspective

The balanced perspective is easily obtained when the logic models developed by the various specialists use the same basic structure. The management perspective logic model of Figure 2 could be modified to resemble more closely the logic models shown in Figures 5 and 6, the financial and EDP perspectives.

In any case, an informed judgement can be made about the relative significance of various auditable issues identified in the different logic models. Such a judgement derives from a balanced perspective.

Actual Accommodation Logic Model

Figure 2 is represented as being the final system logic model. It is not. The final logic model was immensely more complicated. The actual final logic model was used in the way we suggest that Figure 2 be used in this example; that is, from the final model, key controls and functions are identified for further audit examination. There were many more than the three described.

During the actual survey, a large number of functions and information linkages were subjected to preliminary evaluation. From these many preliminary evaluations, the detailed audit program was determined. In fact, Figure 2 was developed during the audit and not during the survey.

Conclusion

Throughout this text, we refer to links between the various systems. These links make the overall system complex. This complexity, in turn, makes the comprehensive audit of such systems difficult to manage. The audit of complex systems is done by breaking down the work into fixed projects and assignments, each with specific goals and fixed resources and schedules. A satisfactory comprehensive audit requires thorough coverage of significant issues. An economic audit achieves this with a minimum of overlap and redundancy in audit effort. The early identification of important links between systems provided by this approach ensures economy in audit resources. It is the argument of this paper that the exploratory approach is the best way to conduct an audit of complex systems.

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